Computational Design of the Low-Loss Accelerating Cavity for the International Linear Collider (ILC)

DOE/HEP SciDAC AST Project:

"Advanced Computing for 21st Century Accelerator Science and Technology"

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Stanford Linear Accelerator Center

2006 NCCS Users Meeting

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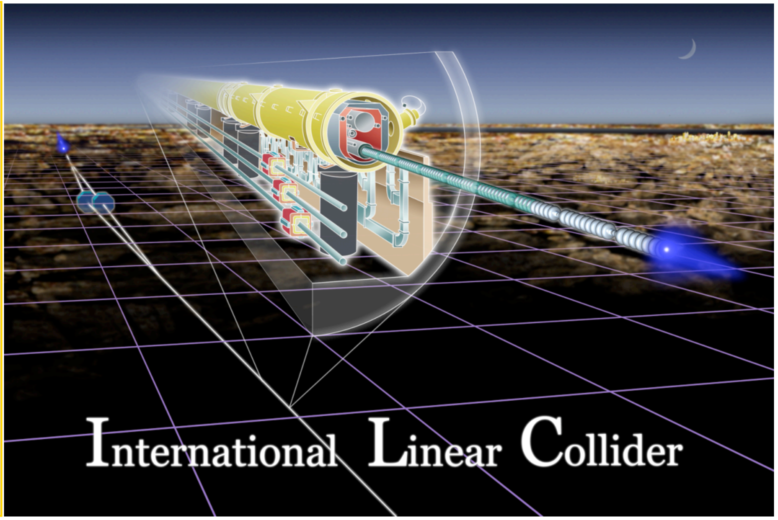
International Linear Collider (ILC)

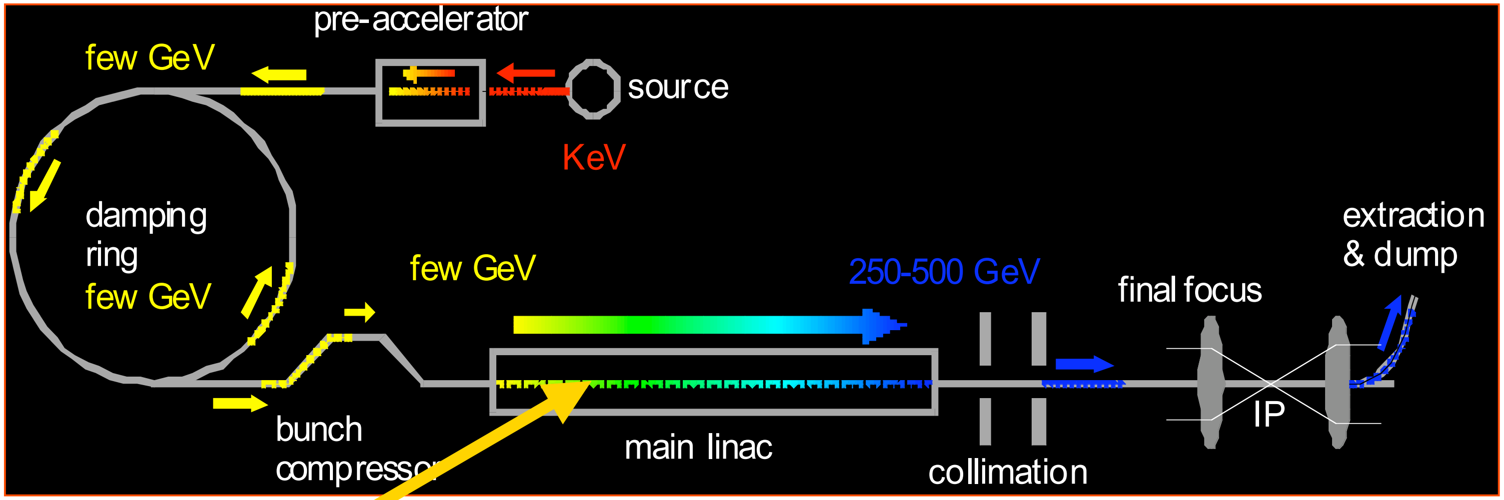
http://www.linearcollider.org/cms/

The ILC is a proposed new electron-positron collider that would allow physicists to answer compelling questions on identity of dark matter to the existence of extra dimensions. In the ILC's design, two facing linear accelerators, each 20 kilometers long, accelerate electrons and positrons to TeV energy using superconducting accelerating cavities.

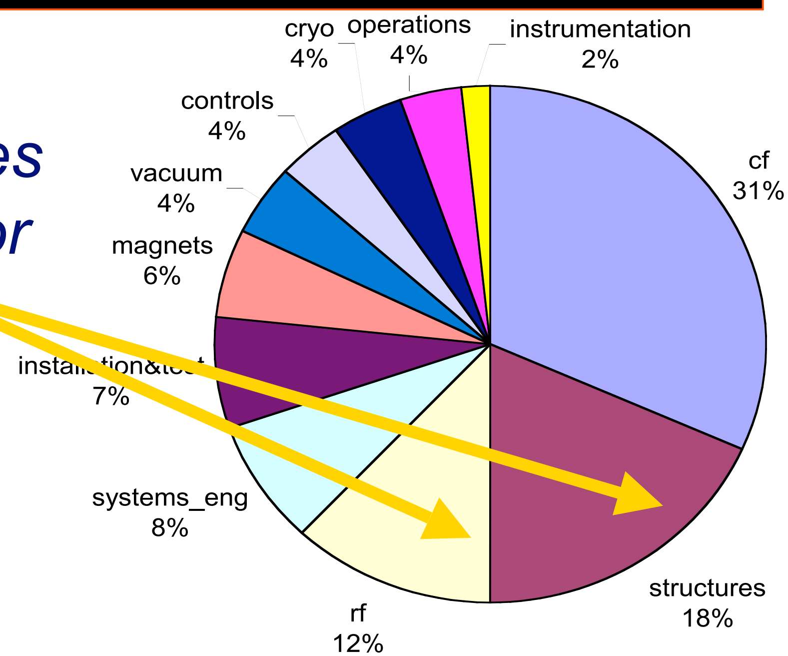
The Global Design Effort will establish the design of the ILC, focusing the efforts of hundreds of accelerator scientists and particle physicists in North America, Europe and Asia.



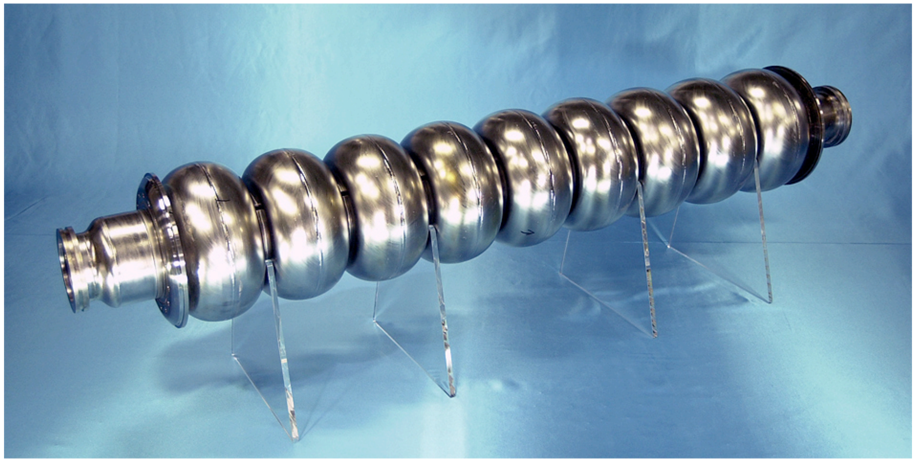
ILC Superconducting RF Main Linac

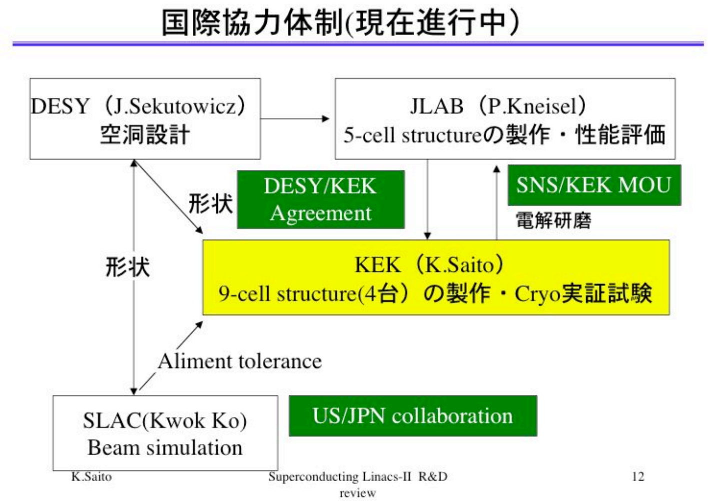


SRF Main Linac constitutes the heart of the accelerator at 30% of its total cost & consists of 20,000 SRF cavities to accelerate the beams to 0.5 TeV energy



ILC Low-Loss Accelerating Cavity Design





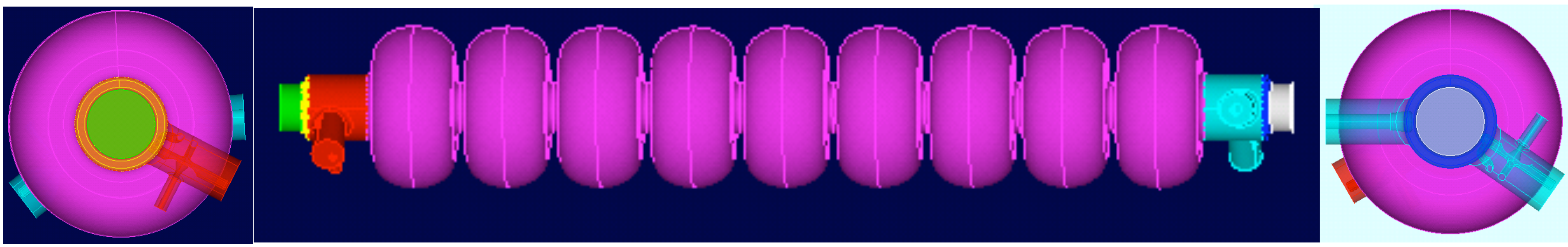
An international team comprising KEK, DESY, FNAL, Jlab and SLAC is developing the Low-Loss (LL) design for the ILC accelerating cavity as a viable alternative to the standard TESLA design.

Single LL cell shape reaches 46.5 MV/m field gradient versus TESLA's 35 MV/m while the LL cavity has 20% lower cryogenic loss.

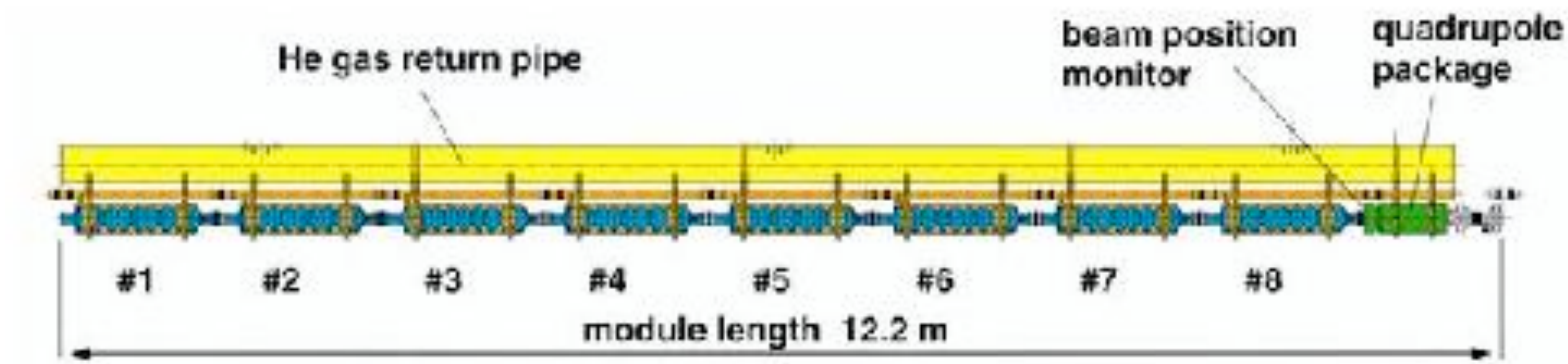
Electromagnetic Modeling of Low-Loss Design

Simulation tasks on X1E under SciDAC AST project:

- *Optimize the LL design for most effective High-Order-Mode (HOM) damping to meet beam stability requirements*



- *Model a multi-cavity cryomodule (e.g. 8 cavities)*



SLAC's Parallel Electromagnetic Codes

Solve Maxwell's equations in time & frequency domains using ***3D unstructured grid*** *and* ***parallel computing***

Finite-Element Basis up to 6th order

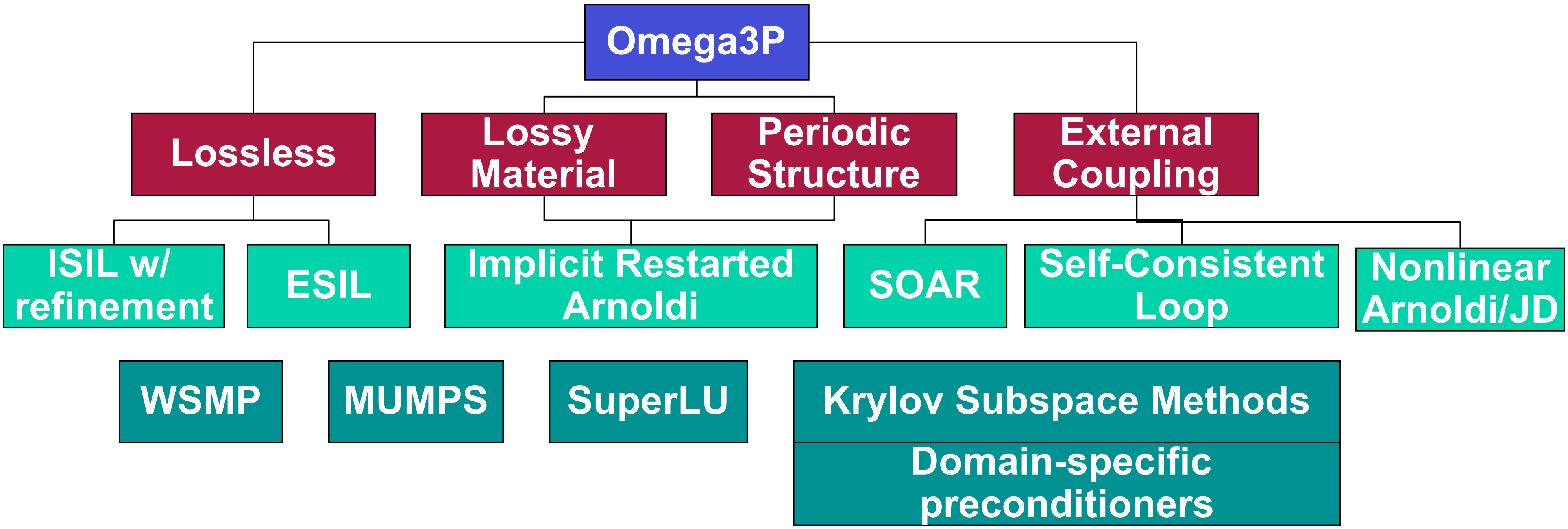
T3P	Omega3P	S3P
↓	↓	↓
Time Domain Simulation With Excitations	**Frequency Domain Mode Calculation**	**Scattering Matrix Evaluation**
↓	↓	↓

Track3P – Particle Tracking with surface physics

V3D – Visualization of Meshes, Particles & Fields

Omega3P for ILC Cavity Calculations

(SLAC, TOPS/SAPP - LBL, UC Davis, Stanford)



- Calculating HOM damping in the ILC cavities requires a nonlinear eigensolver when modeling the coupling to external waveguides (FP & HOM couplers) to obtain the complex mode frequencies as a result of power outflow

Porting Omega3P to the X1E

- *SLAC awarded large allocation on Phoenix in May 2005*
- *First experience of running Omega3P on vector machine*

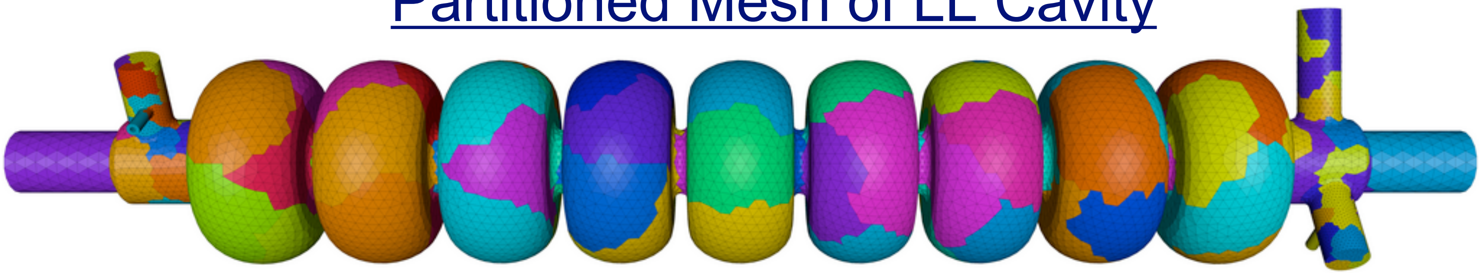
  Much help from multiple NCCS staff members
- *Algorithmic changes to improve performance include*
  - *Replacing METIS by ParMETIS for matrix reordering*
  - *Removing synchronization in Second Order Arnoldi*

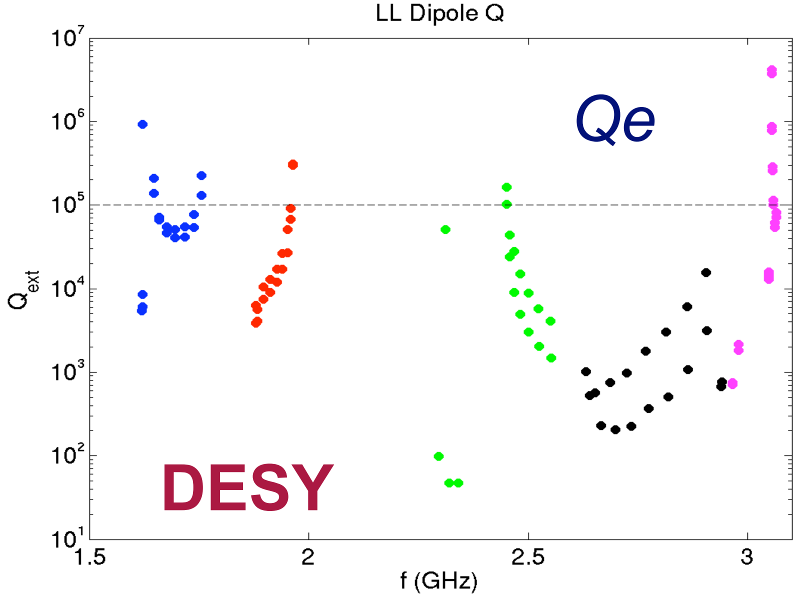
Comparison of 18 eigenmodes on 500K mesh/3M DOFs:

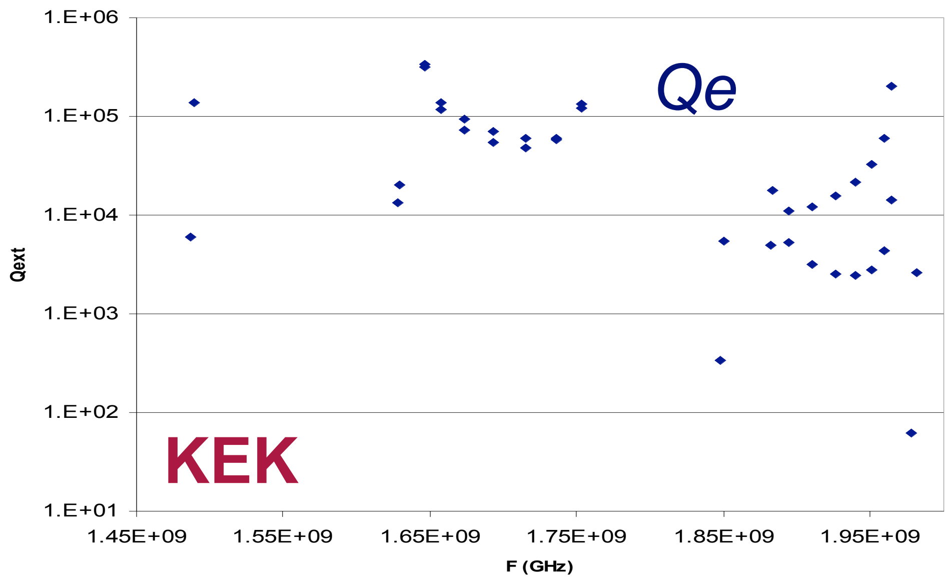
	Phoenix (32 MSPs, allocated with 128 MSPs for memory)	**Seaborg** (32 nodes with 2 tasks per node and 8 threads per tasks, 512 CPUs)
Eigensolver (SOAR) Time	1869 seconds	2114 seconds

HOM Damping in LL Cavity Design

Partitioned Mesh of LL Cavity





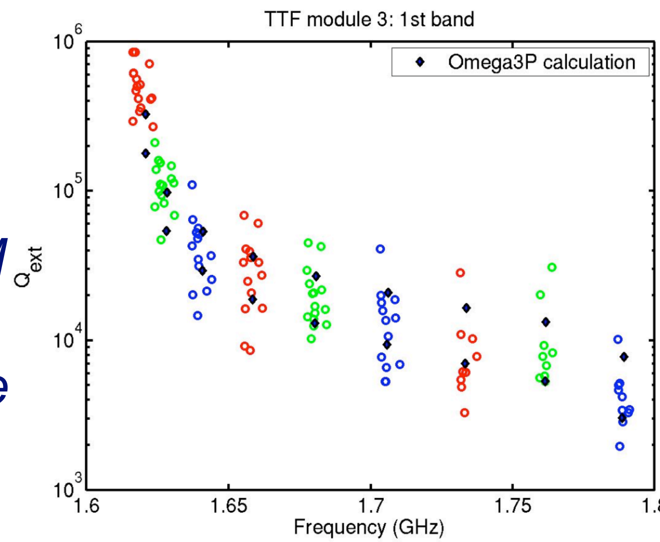


***Omega3P** computes the complex frequency to provide $Qe = \omega_R/2\omega_I$ of dipole modes due to damping by the HOM couplers*

SciDAC 2 Simulation Tasks (1)

- *HOM damping in <u>realistic</u> cavities (Omega3P)*

  - Determination of actual cavity shape with deformations due to loose fabrication tolerances and tuning is important for reliable estimates of HOM damping. Using measured data the deformations will be computed from the Maxwell eigenvalue problem.



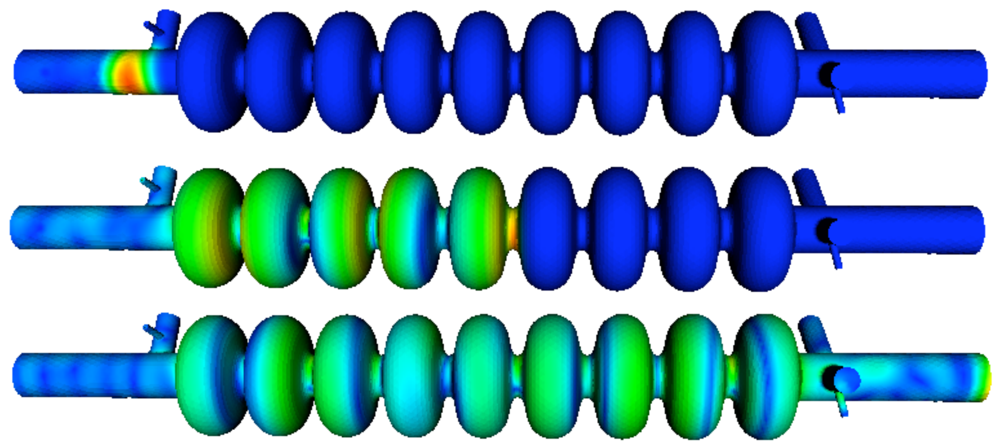
- *Trapped modes in cryomodules (Omega3P)*

  - Systematic search for dangerous modes that can affect stability of beam transport

SciDAC 2 Simulation Tasks (2)

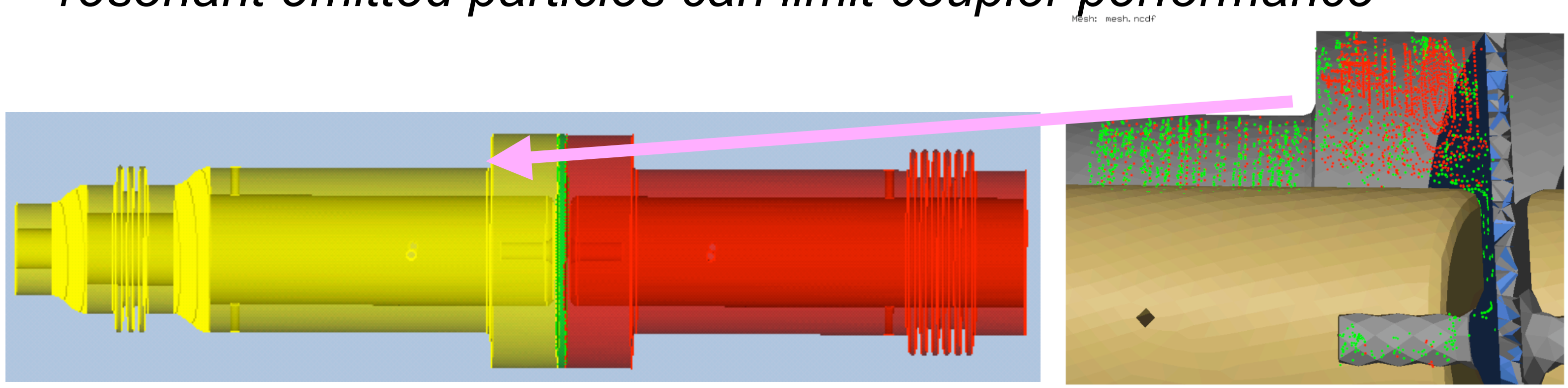
- *Direct wakefield calculations (T3P)*

  - Time domain simulation for accurately computing the impedance spectrum of ILC's beam-line components including the accelerating cavities



- *Multipacting in input couplers (Track3P)*

  - resonant emitted particles can limit coupler performance



SciDAC 2 Planned Collaborations

- *Shape determination and optimization*
  - *- SciOPS, ITAPS, TOPS*
- *Nonlinear eigensolver advancement*
  - *- TOPS*
- *h-p-q adaptive refinement*
  - *- ITAPS*
- *Load balancing for particle simulation*
  - *- ITAPS*
- *Coupled EM/thermal/mechanical modeling*
  - *- TOPS, ITAPS*
- *Code performance optimization*
  - *- PERC and SAP (LBNL, NCCS)*
- *Interactive, remote visualization*
  - *- UCDavis*